Alberta ENERGY

Scientific and Engineering Services

Some Methods of Saving Energy with Fluorescent Lighting

Projects supported in part by the Alberta/Canada Energy Resources Research Fund

Cover Photo: Until recently, only incandescent bulbs could be used in certain lighting fixtures because small lamps were needed. This meant that energy-saving fluorescent lamps could not be used. Today, this is no longer true. Now, mini-fluorescent fixtures equipped with threaded bases can replace incandescent lamps in recessed ceiling lights, for example, or be especially designed for other uses, such as in exit signs.

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page eight.

Some Methods of Saving Energy with Fluorescent Lighting

The amount of electrical energy consumed by artificial lighting systems is largely influenced by the types and numbers of lamps that are used in any particular application. Today, most office buildings and many commercial establishments use fluorescent lighting because it is up to four times more energy efficient than the incandescent lighting commonly found in homes. However, fluorescent lamps are not used for every lighting situation in offices and businesses; incandescent lamps are still used in exit signs, emergency lighting and recessed ceiling fixtures.

While it is possible to save electrical energy by simply switching off lamps when they are not needed, or using lower wattage lamps in some situations, this does not apply to all lighting applications. For instance, lower wattage lamps and the lower light level they produce may not be acceptable in some circumstances. Similarly, one might be tempted to use low pressure sodium lamps, which are more energy efficient than fluorescent lamps and are up to 10 times more energy efficient than incandescent lamps, but the pronounced yellow colour they produce makes them unsuitable for most office and business environments.

Consequently, the positive features of fluorescent lighting have continued to foster research and development work aimed at improving the energy-efficient properties of fluorescent lamps and expanding their uses. Two research projects with these goals in mind were supported by A/CERRF in the mid-1980s.

Design Analysis of an Electronic Fluorescent Lamp Ballast

Unlike incandescent bulbs, which contain a filament of very fine wire that glows white-hot when an electrical current flows through it, gaseous discharge arc lamps, such as fluorescent, metal halide and both high and low pressure sodium types, produce light when electricity is passed through a gas. Also, unlike incandescent lamps, the gaseous discharge types will burn out instantly if they are operated at a constant high voltage. To accommodate this latter characteristic, devices known as lamp ballasts are used to initially supply a high voltage to start the arc in the lamp and then provide a controlled voltage after the lamp fires. Because ballasts are the greatest energy-consuming components of fluorescent systems, it is believed that improving their design will lead to lower energy consumption.

Until recenty, most ballasts were "line frequency magnetic" types, which are large and heavy, and have energy efficiencies of approximately 75 per cent. They also generate sufficient heat to place an extra burden on air conditioning systems in some buildings.

Although electronic ballasts, which are more energy efficient than magnetic ballasts, have been introduced by some manufacturers in recent years, they are expensive and their operating characteristics are not necessarily well matched to the voltage demands of fluorescent lamps. Consequently, Comtrac Industries Limited of Airdrie, Alberta, initiated a research program, with financial assistance from A/CERRF, to design a better energy-saving electronic ballast suitable for fluorescent lamps.

Design Challenges

One of the difficulties in designing a ballast for fluorescent lamps is finding a way to supply appropriate voltage to a lamp requiring a variable, non-linear current that changes with time as the lamp progresses from ignition, through warmup, to steady-state operation.

Most fluorescent lamps currently in use are "rapid start" types. They require only a few hundred volts during ignition, as opposed to the several thousand volts that are needed by older "instant start" types. This is accomplished by constantly supplying power to a warming circuit which maintains the temperature of the cathodes at a prescribed level. At least one manufacturer makes an energy-saving ballast that uses a solid state switch to turn off the heater current after the lamp reaches steady state, but it is claimed this substantially shortens the life of the lamp.

Other aspects of fluorescent tubes that must be considered when designing a ballast include static, low frequency and high frequency characteristics; positioning of the lamp case grounding strip; pulse width modulation; and the relationship between power frequency and light output.

Alternative Ballast Designs

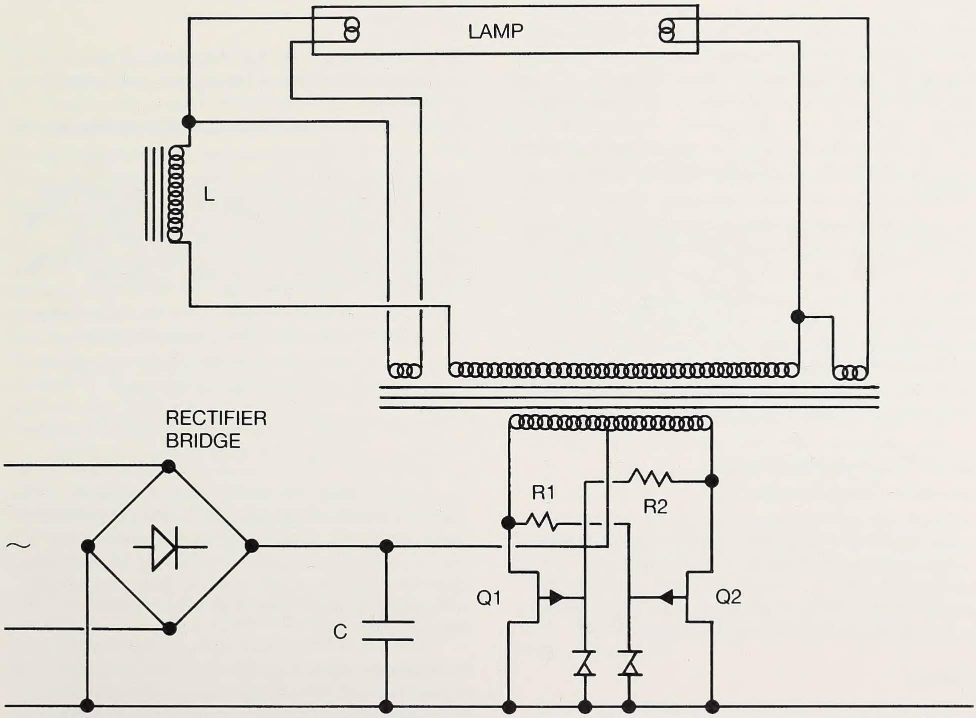
Several configurations for ballast circuits were proposed and tried by the contractor. Each was found to have its own set of tradeoffs in terms of both generating enough initial voltage to fire the lamp, and the ability to switch to a lower current as the lamp reached steady state.

Concepts such as direct current lamp excitation, uni-polar lamp excitation, bi-polar lamp excitation, a transformer drive circuit, and use of a direct current bridge were proposed and analysed.

The transformer drive system was regarded as the most suitable. It is essentially a solid state version of the conventional line frequency ballast, but it is much smaller.

While currently available electronic ballasts are from four to eight times as expensive as magnetic ballasts, the researchers concluded that a single electronic ballast, which incorporates a transformer drive system, could operate more lamps than could a conventional ballast, thus reducing the cost somewhat. However, if electronic ballasts are to become cost competitive with magnetic ballasts, the researchers concluded that a new generation of high voltage integrated circuits for switching power supplies will be needed.

Transformer Drive Circuit Diagram



(Source: *Design Analysis of an Electronic Fluorescent Lamp Ballast,* Comtrac Industries Limited, August 1985)

Demonstration of Mini-Fluorescent Lighting

Although fluorescent lamps long have had a cost advantage over incandescent lamps, the latter are still used in downlighting situations, exit signs and emergency lighting. This situation may be about to change, however, because compact fluorescent lamps capable of being used in these applications recently became available. Consequently, J.A. Love of the University of Calgary's Faculty of Environmental Design, in association with Clearview Lighting Ltd., a manufacturer of compact fluorescent fixtures, assessed several potential applications for these new lamps, as well as their performance, in a small number of field installations.

Design Characteristics

The use of incandescent lamps has persisted in ceiling-recessed fixtures (''pot'' lamps) because their colour spectrum and their ability to produce a concentrated beam of light from a single point source are desirable characteristics for any lamp used in this particular application. Of course, the fact that no other type of lamp with these attributes was available meant that incandescent lamps were the only logical choice. However, enhanced spectrum fluorescent lamps now on the market can approximate visible light emissions of incandescent bulbs. Their availability in compact models, which can be connected at only one end to fixtures, opens up new marketing opportunities for fluorescent lamps.

Pin-mount, or ''P-type,'' mini-fluorescent lamps, are made by several manufacturers. They are up to 19 cm (7.5 in.) long, but adaptors which include the ballast and screw mounts add another 5 cm (2 in.) to their overall length, making a mini-fluorescent lamp assembly approximately 8 cm (3 in.) longer than conventional 25 to 60 watt incandescent bulbs. Newer screw-type, or ''S,'' lamps are shorter; their overall length is less than 8 cm (7 in.).

Mini-Fluorescent Versus Incandescent Lamps

Compact fluorescent lamps and the incandescent bulbs they might replace in specific circumstances were compared according to their costs and 14 performance factors. These included light output, energy efficiency, lamp life, light distribution, safety, appearance and colour characteristics.

Costs

If a screw-type compact fluorescent lamp is being considered as a replacement for an incandescent bulb, it can be screwed into existing light fixtures as easily as the incandescent bulb. Therefore, labour costs associated with relamping are the same, but the capital costs are quite different; mini-fluorescent lamps cost upwards of $25, while incandescent

10.5 watt mini-fluorescent lighting system used without a reflector in a mechanical services tunnel.

(Photo courtesy of J.A. Love, University of Calgary)

bulbs sell for as low as $1. Therefore, if mini-fluorescent lamps are to be seriously considered as replacements for incandescent types, they must operate at substantially lower costs over the long term.

In comparing the operating costs of incandescent versus mini-fluorescent products, the following were considered in a discounted cash flow analysis, assuming a two-year operating period and long-life incandescent lamps as a suitable reference:

- the cost of energy to operate the lamp (including the ballast in the case of fluorescent lamps);
- the cost of energy (in air-conditioned spaces) to remove the heat generated by lamps;
- the cost to replace burned-out lamps; and
- the cost of labour to replace burned-out lamps.

Two options were chosen: (1) bulbs that were operated continuously, and (2) those that operated intermittently (10 hours a day, five days a week). Also, analyses were performed for individual lighting situations, such as in exit signs, in recessed fixtures with reflectors, and in low light level situations without reflectors.

For example, when a single 10.5 watt compact fluorescent fixture is used in place of two 25 watt incandescent bulbs in an exit sign under continuous operating conditions for two years and a typical case of a marginal electricity cost of $0.05 a kWh, it is more cost-effective to use 10 000-hour mini-fluorescent lamps than 2 500-hour incandescent bulbs. Similar conclusions were reached for

Custom mini-fluorescent exit lamp system.

(Photo courtesy of J.A. Love, University of Calgary)

downlighting applications, but the economics are not as attractive when lamps are used only occasionally.

Performance Characteristics

The light output of the highest-wattage compact fluorescent lamp currently available (13 watts) is 900 lumens, which is substantially below the 1 400 and 2 800 lumens that are produced respectively by 25 watt and 150 watt incandescent bulbs commonly used in recessed fixtures. This means that in some downlighting situations, even mini-fluorescent lamps equipped with reflectors might not be able to satisfy building code requirements for light levels. Also, the length of mini-fluorescent bulbs can be a problem in some recessed lighting situations because they protrude beyond the bottom of the fixture, creating a safety hazard and producing glare.

On the positive side, however, tests showed the colour rendition of mini-fluorescent lamps was substantially different from regular fluorescent lamps and approximated the colour spectrum produced by incandescent lamps.

In exit signs, mini-fluorescent lamps rated as low as 7 watts can be used in place of two 25 watt incandescent bulbs without any reduction in light level. Also, mini-fluorescent lamps seem especially suited for emergency lighting. This is because new building codes now require more extensive emergency illumination than in the past, a requirement that cannot be met by incandescent lamps because the power they would require could easily exceed the electricity-generating capabilities of existing emergency power generation systems. Tests have shown, however, that the low power demands of mini-fluorescent lamps would not severely tax emergency power plants.

Field Installations

Compact fluorescent installations at five locations (four in Calgary, one in Red Deer) were studied and assessments were made of lamp life, light output, ease of installation, cost effectiveness and energy consumption.

The installations included:

- 10.5 and 14.5 watt (lamp and ballast) downlights, with reflector, in office corridors and washrooms in an office tower, a hospital and a court-house;
- 10.5 watt exit sign fixtures at an airport terminal building, a technical college and a hospital; and
- 10.5 watt fixtures without reflectors in a mechanical room or its services tunnel.

Overall, it was found that compact fluorescent lamps rated at 10 000 hours were being operated continuously for more than 17 000 hours. This caused a re-assessment of cost comparisons and made mini-fluorescent lamps even more attractive in most instances.

Downlight System Discounted Total Capital and Operating Costs Over a Two-Year Period

System Type	$0 Relamp Cost		$1 Relamp Cost		$5 Relamp Cost	
	kWh Cost		kWh Cost		kWh Cost	
	$0.02	$0.05	$0.02	$0.05	$0.02	$0.05
mini-fluorescent 10 000 hrs lamp life $70/unit initial cost	$86	$91	$88	$93	$95	$100
mini-fluorescent 17 000 hrs lamp life $70/unit initial cost	$73	$78	$74	$79	$77	$82
150 W incandescent 2 000 hrs lamp life $4/unit lamp cost	$80	$150	$88	$160	$121	$192
75 W incandescent 2 000 hrs lamp life $3/unit lamp cost	$48	$84	$57	$92	$89	$125

(Source: *Demonstration of Mini-fluorescent Lighting: Phase II Report,* J.A. Love, University of Calgary, March 1987)

Exit Sign System Discounted Total Capital and Operating Costs Over a Two-Year Period

System Type	$0 Relamp Cost		$1 Relamp Cost		$5 Relamp Cost	
	kWh Cost		kWh Cost		kWh Cost	
	$0.02	$0.05	$0.02	$0.05	$0.02	$0.05
mini-fluorescent 10 000 hrs lamp life $25/unit initial cost (small order)	$36	$42	$39	$44	$46	$52
mini-fluorescent 10 000 hrs lamp life $18/unit initial cost (large order)	$30	$35	$32	$37	$40	$44
mini-fluorescent 17 000 hrs lamp life $25/unit initial cost (small order)	$28	$33	$29	$34	$32	$38
mini-fluorescent 17 000 hrs lamp life $18/unit initial cost (large order)	$21	$26	$22	$27	$26	$31
2 x 25 watt incandescent 2 500 hrs lamp life $1/lamp cost	$30	$50	$38	$61	$67	$90
2 x 11 watt incandescent 2 500 hrs lamp life $1/lamp cost	$18	$28	$29	$39	$72	$83

(Source: *Demonstration of Mini-fluorescent Lighting: Phase II Report,* J.A. Love, University of Calgary, March 1987)

Exit Signs

When used in exit signs, it was found that mini-fluorescent lamps provided the same light output as incandescent lamps, but at a lower wattage, and consumed less energy while generating half as much heat. Not only were exit sign enclosures no longer warped and damaged by excessive heat, but it was observed that use of mini-fluorescent lamps eliminated power overloads on the corresponding emergency power circuits.

Downlighting

In downlighting installations, mini-fluorescent lamps were equipped with screw bases, making relamping as simple as with incandescent lamps. In some, but not all locations, the lower lumen level of 14.5 watt fixtures failed to satisfy 1985 Alberta Building Code requirements. The same situation was observed for the 10.5 watt fixtures.

Low Light Applications

A 10.5 watt, reflector-less, mini-fluorescent fixture used in a mechanical services tunnel provided an adequate light level of 600 lumens. However, when the same fixture was used to replace incandescent lamps in luminaires in a mechanical room, it was found that the screw-based bulb protruded beyond the bottom of the luminaire. The mini-fluorescent fixtures were removed.

Conclusions

It was concluded that at a marginal electricity cost of $0.05 a kWh, compact fluorescent lamps are a cost-effective substitute for continuously operated incandescent lamps, but in some downlighting situations, lumen output may be insufficient to satisfy building code requirements.

Particularly when used in exit signs, the chief advantages of mini-fluorescent lamps are:

- elimination of heat damage to enclosures;
- reduction of the amount of wiring;
- reduction of the electrical load on emergency power systems;
- provision of as much light, but at a lower wattage than incandescent lamps; and
- a substantially longer life than incandescent lamps.

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